TRIZ-Assisted Frugal Innovation

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Abstract. Frugal Innovation is an unorthodox approach to product design recognized in many developing countries, where creativity is essential to generate solutions that increase economic and social value while fewer resources, usually taken for granted are available, if at all, keeping the focus on delivering the main function with state-of-art technology. Big companies are also applying a similar philosophy, called "disruptive innovation" or "reverse innovation", to meet the needs of potential customers with limited buying power and enter new markets, introducing novel business models. The peculiar attentiveness to the sparse usage of raw materials and resources offered by frugal innovation is also relevant for rethinking the design process in view of sustainable development.

The present paper will review some examples and show how the TRIZ thinking frame can effectively assist frugal innovation projects, formulating the Ideal Final Result and formalizing a dedicated process, based on Resource Analysis, Functional Analysis and Trimming.

Keywords: Frugal innovation · Resources · Ideal Final Result

1 Frugal Innovation: Definitions, Features and Methods

Frugal Innovation emerged as an unorthodox approach adopted in the Global South to address basic needs and offer state-of-the-art solutions [1] characterized by high level of creativity. It was sparked in India, favoured by several socio-economic and cultural factors [2], i.e. the need for "affordable excellence", availability of technological expertise and a positive attitude towards frugality. It praises solutions that allowed to get more value a better social impact from limited resources and at lower cost. Frugal Innovation states a different Value Proposition, reversing the notion of product innovation based on added functionalities (previously in the "nice to have" space foreseen by the Kano model) and increased complexity, leading to a more attractive and expensive high-end product.

Moreover, the ability to generate a positive impact on sustainability and progress for a larger group of people otherwise out of the picture is thought to be a source of soft power and influence [3], aligned with the Sustainable Development Goals [4]. It has been recognized and investigated with growing interest in the scientific community, in association with keywords like Bottom of the Pyramid, Emerging Markets, Jugaad, Reverse Innovation, Disruptive Innovation, Low-Cost Innovation [5]. It is expected to be in demand also globally, in view of the growing need for social innovation and

sustainability [6]; in fact it quickly found a big resonance in the western countries [7] as the a way to address new urgent global needs world-wide, i.e. connecting a larger base of customers with limited purchasing power. In Europe efforts are made to define the relevant space with several studies requested by the European Commission [8, 9], where it emerged that challenges posed by environmental awareness, climate change, excessive complexity and financial austerity would increase frugal solution success in Europe, along with the opportunity to reformulate design approaches for cheaper and smarter solutions.

Multinational companies like GE, Siemens, Philips, Bosch already recognized in the early 2000s that affordability brings about big opportunities to open market segments in emerging countries and allows to retain market position; in order to diffuse products and solutions it is possible to sacrifice some "nice to have features" while focusing on the delivering of the minimal function with state of art technology, bridging the gap between pricey products and the basic needs of customers without money. For a product success, defeaturing was recognized not to be enough, but a need to rethink the entire design process was stated, paying attention to the local peculiarities, thus paving the way for the so-called "Disruptive Innovation" or "Reverse Innovation" [10], later also called "Corporate Frugal Innovation" [11].

A big effort has thus been undertaken to define Frugal Innovation as a concept and frame it as a process. At first, many definitions based on descriptive criteria to qualify a solution as frugal have been proposed, highlighting cost reduction, concentration on core functionalities, and optimized performance level [12]. In [13] a longer list of features is compiled: Affordability, Simplicity, Robustness, User friendliness, Economies of scale, Quality, Locality, Sustainability, this last one underlining the opportunity to support greener solutions.

Most of literature contributions offer definitions and identify processes, gathering countless case studies and formulating statements to changing the operating mode, mostly adopting empathic methodologies, but pragmatic proposals of a structured workflow to organize a frugal innovation project are still rare. A seminal example is presented in [14], where a combined approach of VAVE (Value Analysis/Value Engineering) and TRIZ tools allows to removing all unnecessary features from a product and reducing the cost. The workflow is organized according to the SAVE Template [15], where TRIZ is used after a value Analysis, during the creativity phase, focusing on Trimming and Function Oriented Search applied on the generated function modeling and identification. In this paper it will be discussed how TRIZ could offer a stand-alone workflow dedicated to frugal innovation, offering the tools to overcome technical issues. The list of Frugal innovation features can be used as idea-downselection criterion.

2   TRIZ Tools Relevant to Frugal Innovation

The tools that so far have been identified in literature relevant to Frugal Innovation are Trimming and Function Oriented Search: this is consistent with Frugal Innovation most evident attributes:

– Focus on functionality: a previous step of Function Analysis (be according to VAVE or Modern TRIZ schema) to identify the most expensive functions and establish a function ranking, along with a systematic the pathway for simplification;
– Defeaturing: trimming and radical trimming to maintain the focus on main functions and redistribute or eliminate the remainder, so as to "do more with less";
– Function oriented search to "do better and cheaper", leveraging from existing alternative technologies and adapting to frugal environments.

In this paper the focus is on a workflow entirely based on TRIZ, and the discussion on the relevance of approach offered by other TRIZ tools, like:

– Ideal Final Result (IFR): to give an essential formulation of the need to cover;
– Resource Analysis: to systematically analyze what is available to solve the problem;
– Function Level Analysis/Trend of increasing Coordination: to enhance the focus on functionality and take the appropriate steps in the decision-chain;

These observations led to the identification of a dedicated TRIZ-based workflow, as explained in Sect. 3.

As far as the S-Curve analysis is concerned, the classic TRIZ theory foresees a First and a Transitional Stage with focus on delivering the Main Function and a Second Stage, when the product reaches market success, when functionality increases quickly to gain new customers; a frugal approach would need to review this formulation.

3   TRIZ-Assisted Systematic Process for Frugal Innovation

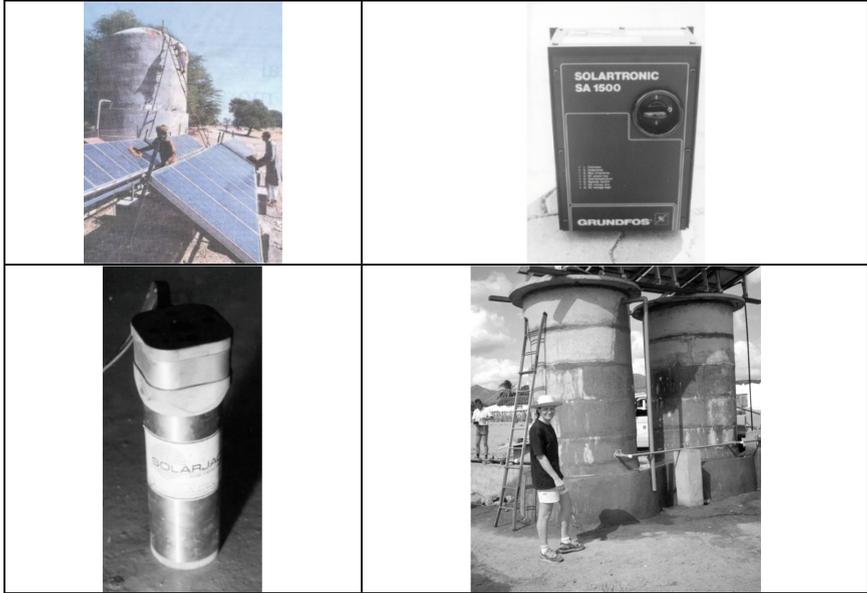The proposed workflow foresees the following steps:

1. Ideal Final Result Formulation
2. Resources Analysis
3. Level of Functionality – Trend of Decreasing Human Involvement
4. Idea generation
5. Selection vs. Frugal Innovation Criteria
6. Business model formulation
7. Implementation

A case study to showcase this workflow in presented in Sect. 4.

4   Example: GIZ Water Supply Project in Uganda

Water is essential for any civilization. Still today about two billion people don't have access to clean and potable water. Water scarcity already represents one of the most important global challenges [16], expected to be exacerbated by the climate change, representing a crucial problem to be solved for sustainable development. The following example reports a frugal innovation experience from The GIZ project in Kabale, Uganda, addressing a water supply scarcity issue.

Typically, western countries want to address this problem with the western State-of-the-Art: use high technological solutions to pump and clean water. The current solutions are photovoltaic pumping systems. They consist of the following basic components (Fig. 1):

Fig. 1. Usual non-frugal approach components: top left, clockwise: Photovoltaic Modules, Inverter, Water Tank & Piping, Motor/Pump combination

- PV Modules that have to be imported and that are expensive;
- Inverter to convert the PV power into power to drive a submersible pump: this part is as well expensive and produces in developed countries;
- Submersible motor/pump combination: also to be imported;
- Water tank, pipes, hydraulic fitting (usually available in the country), which make ∼10% of whole value chain.

Such a high technology system is furthermore usually designed for usage by proper trained persons and for good environmental conditions. The operation is done by a switch (on/off) and the operation is indicated by a LED: green – system operates, red – system failure. A repair on site by local people is not possible. The following pictures show the elements of such a PV Pumping System.

It is evident that in such a case an ordinary well-known solution would represent not only a non-affordable product, but also deliver an unsatisfactory performance regarding the life-cycle behavior. It is not adopted to the needs, skill set and requirements onsite.

We will now demonstrate how a TRIZ-assisted frugal innovation approach would address this issue by using the proposed workflow.

4.1 Ideal Final Result (IFR)

The IFR can be formulated as a **System, that always and safely delivers water** by itself.

4.2 Resource Analysis

A Resource Analysis was performed, leading to the list of the all available water reservoirs:

– Water itself
– Water holes (water is scooped)
– Deep wells
– Surface wells
– Rivers
– Handpumps
– Sakieh (Fig. 2)
– Atmospheric Humidity

Fig. 2. Sakieh

This list will also serve as a checklist for Trimming (described in Sect. 4.5), while brainstorming how to redistribute the functions to the external environment.

4.3 Level of Functionality – Trend of Decreasing Human Involvement

In this chapter we detect the level of functionality for the different resources, so as to assess the adaptability to the selected frugal environment. The Trends of Decreasing Human Involvement is used as a tool since it is very helpful as a rating criterion as a system evolves. The levels are defined according to Fig. 3:
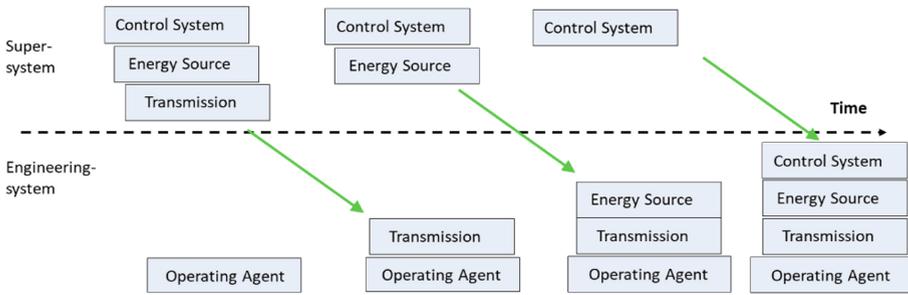
Fig. 3. Template for level of functionality analysis for the different resources

The engineering system ALWAYS consists at least of the operating agent. That is the functionality it was designed for. Control system, energy source and transmission are part of the super system. Over time transmission, energy source and control may move from the super system to the engineering system. This includes a reduction of human involvement. E.g. 1st automobile was the chassis and the motor. The driver had to do everything – start motor by hand, move wiper, move flasher, etc. Now we have lots of assistant systems in a car that help support the driver and we are nearby "autonomous driving" where even the control system moved to the engineering system.

For the resources listed in Sect. 4.2, human involvement is very high for all systems, but the handpump and the Sakieh.

One could improve the reduction of human involvement by using motorized systems like diesel fueled systems or photovoltaic systems. For the motor pumps, human involvement would be needed to start/stop of the system, refueling and maintenance. The operation affords technical expertise, but since combustion vehicles are well known, the skills are available. A system where controls are moved as well is a photovoltaic system. It operates fully autonomous (Fig. 4).
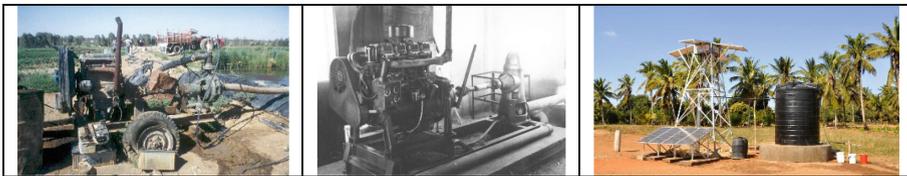

Fig. 4. Motorized systems used for water supply

4.4 Idea Generation: From Resources

As already presented, there are already existing solutions available to pump water with different levels of human involvement. The more autonomous the engineering system is, the more complex it is (and thus usually more expensive). So, the higher these solutions rank according to the Trend of Decreasing Human Involvement, the less frugal they are. **The frugal approach aims to concentrate on what is the maximum**

reduced functionality in order to meet the fundamental basic need. And based on this thought to develop ideas.

In this example the following ideas have been generated by asking: "How can *<resource>* help to pump water in the easiest way?".

A possible list of concepts in this case are reported below:

Fog nets collect the water out of the atmosphere. There is no pumping needed, no mechanics. It is simple, can be built by anybody on his own. But the capacity is limited and depends on the air humidity (Fig. 5).

Fig. 5. Fog nets

Water Wheel Pumps (Fig. 6) are simple constructed pumps for low heads ($\sim$6 m). They consist of a tube that is wind up in a spiral towards the middle. This spiral is mounted max. half sunk in the river. The flow of the river rotates the spiral und by this the water is pumped. This again is a very simple construction that can be made on-site as well.

Fig. 6. Water wheel pumps

Handpump with motor (Fig. 7) is a simple solution to move the transmission and energy to the system. Instead of the person pumping the water, a motor does the job. If it is not working, you can still pump manually. As motor an electric motor power by PV can be used which then needs again to be imported. An alternative could be a wind powered pump, constructed out of available waste materials.
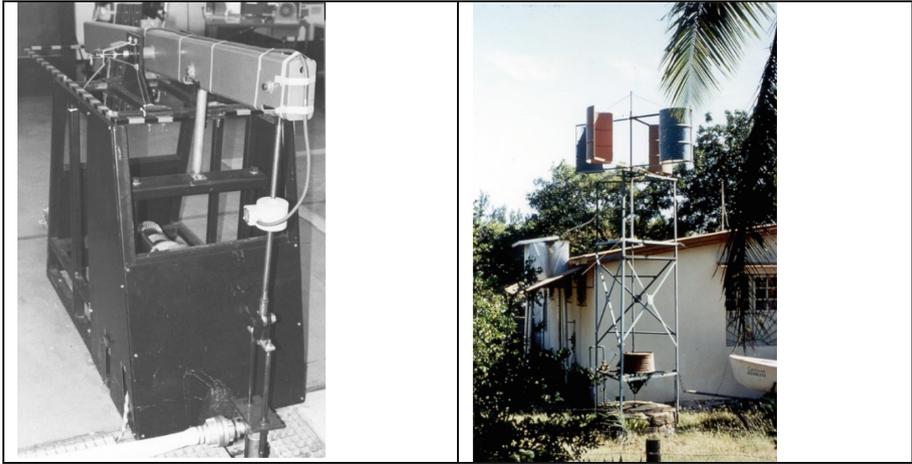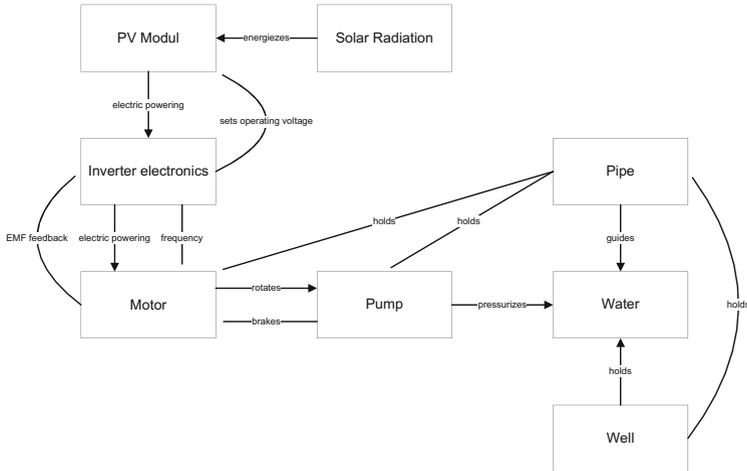

Fig. 7. Handpump with motor

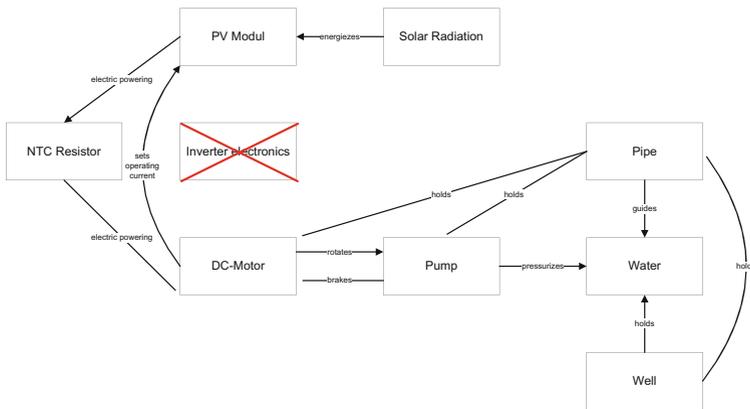## 4.5   Idea Generation: Trimming

Another way to find ideas for solution is to use the trimming tool of TRIZ. For an existing system a function analysis is performed. Then trimming is used to simplify the system down to its basic functionality, fitting very well the frugal philosophy.

In the shown example we have a photovoltaic system. The solar irradiation energizes the PV module with photons. They are converted into electric current and power the inverter. The electronic inverter converts the electric power into AC current with variable frequency. This is powering the motor that feeds back the EMK as a control signal to the inverter. The motor rotates the pump and pressurizes the water in the well into the pipe. The Function Model is shown in Fig. 8.

In a first round of trimming (Fig. 9) the inverter unit was put at disposal. The task to solve was: how can the PV module power the motor directly? And the solution should be as simple as possible. The following figure shows one solution idea. Replace the inverter by a negative temperature coefficient (NTC-) resistor and a DC motor. This would work under less efficiency, but as reduced cost of about 1.000€ and much simpler.
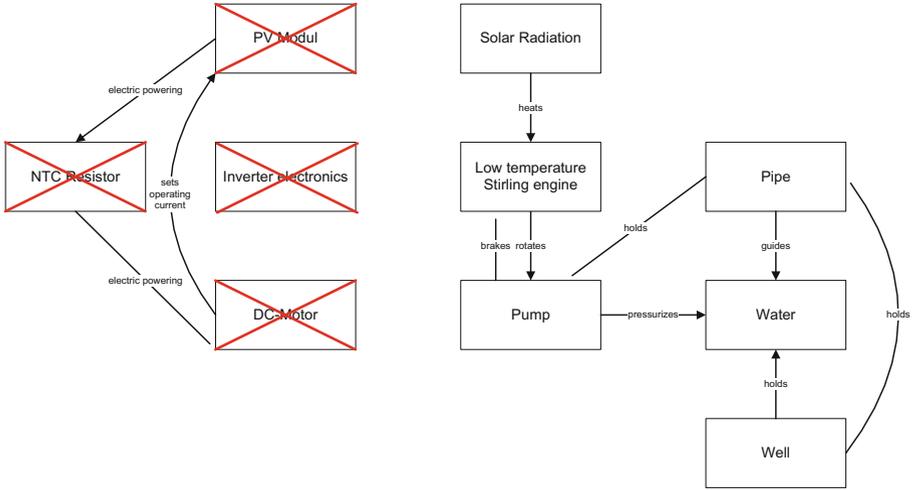
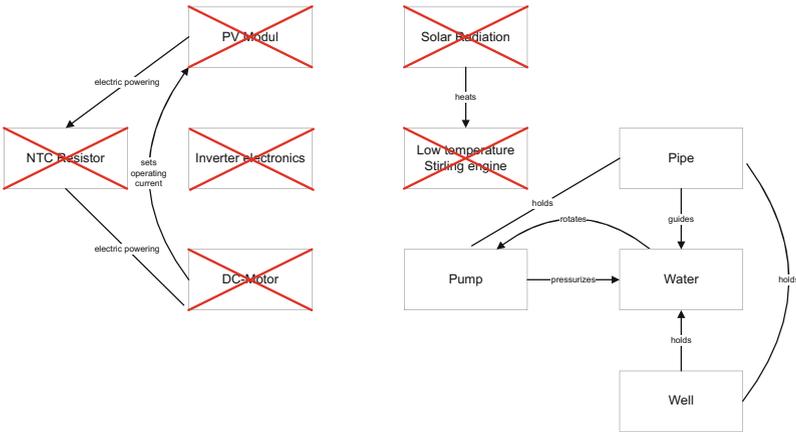**Fig. 8.** Function Model of a photovoltaic system to power a water pump

Fig. 9. Function Model after trimming the inverter unit

In a further step additional trimming is done (Fig. 10): Trimming of PV module, NTC-resistor and DC-motor. As a new component a low-temperature Stirling engine (LTSE) could move the pump. An LTSE is a low-tech product that can be manufactured in the local country.

Further trimming of solar irradiation usage and LTSE (Fig. 11) leads to the question if the water can pump itself, getting closer to the formulated IFR? A solution was show above with the water wheel pump, that can be built easily as well on site.

Fig. 10. Function Model after trimming the PV module

Fig. 11. Function Model after trimming solar irradiation

4.6   Selection vs. Frugal Innovation Criteria

For the selection of the best technology under frugal conditions, we have defined
FOR THIS PROJECT the following criteria, normalized between 1 and 10 for com-
parability (Table 1):

- Performance (1 worse-10 good): How good and continuously the system is per-
  forming, quantified by water flow
- Cost (10 worse-1 good): Cost of the system in the site of application
- Usability (1 worse-10 good): States to extent to which the solution can be imple-
  ment locally, i.e. percentage of locally manufactured components

Table 1. Idea down-selection according to frugal-criteria

	Performance	Cost	Usability	Transfer function
Weight	3	8	10	
Fog Nets	2	8	8	150
Water Wheel Pump	4	8	5	126
Handpump with electric motor	8	4	4	96
Handpump with wind power	4	7	7	138
PV pump	9	1	6	95
PV pump with NTC-resistor	7	4	8	133
LTSE pump	5	5	7	125
Dieselpump	10	2	8	126

In this list Performance maps Quality, Cost maps to Affordability and Usability maps to Simplicity, Robustness, User friendliness, and Locality, mentioned before.

The transfer function is calculated as:

$$F = \text{Performance} \times \text{weight} + \text{Cost} \times \text{weight} + \text{Usability} \times \text{weight}.$$

This shows that under the given assumptions fog nets and handpumps powered by wind make great sense.

4.7 Business Model Formulation

When the technology was selected the last step is to define a business model that will work for the manufacturer and for the customer. This will be based very much on the local conditions. Ideally the technology should be available/manufacturable locally.

5 Conclusions

The idea of frugal innovation addresses the needs of the bottom of the pyramid and allows to opens new business opportunities in new markets. A TRIZ-assisted workflow to generate frugal solutions, based on the understanding of the basic functionality needed in the target country for the product, has been presented, where the frugal thinking permeates the process at all stages. The TRIZ tools "IFR", "Resource analysis" and "Trimming" are valuable tools to generate ideas for a frugal product. The presented structured approach showed that TRIZ is a very valuable tool to assist frugal innovation; the next step will be to wholly deploy a TRIZ workflow for full optimization.

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